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For Period 1 June 1980 to 31 May 1981

TWO-DIMENSIONAL MESH ADJUSTMENT ALGORITHM

Prepared for:

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During the fourth year of research, the gradient and truncation error minimizing mesh adjustment algorithms have been applied to a reactive flow problem in one dimension and to basic illustrative examples in two dimensions. The methods increase the accuracy of a numerical solution with a fixed number of nodes. The storage needed for lower dimensional calculations is reduced, which makes higher dimensional ones feasible.

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I RESEARCH TASKS

The general objective of the on-going research is to establish a transformation of coordinates that facilitates the finite difference solution of partial differential equations in two independent variables. The following tasks describe the plan we have been following to achieve this objective.

Task 1. Identify Useful Coordinate Transformations

The defining equations for the truncation error and gradient-minimizing transformations to a rectangular domain were presented in the proposal. The usefulness of transformations derived from other functionals will be assessed. The one-dimensional results suggest that proper weighting of the components of the gradient can be especially useful. Introduction of an interior boundary point and transformation to a polar net, rather than a rectangular one, are indicated where the solution is anticipated to have either localized or ring-shaped regions of large variation.

Task 2. Investigate Type-Dependence

The present transformations are clearly applicable to elliptic boundary value problems. How well they apply to parabolic or hyperbolic initial value problems will be investigated. Comparison with the approximate Lagrangian, flow-following transformations of Yanenko is needed.

Task 3. Apply Transformation Method

Application of the appropriate transformation to a practical problem previously solved in another way will demonstrate the usefulness of the coordinate trandormation method.

II STATUS OF THE RESEARCH

The result of this year's effort has been to establish a firm base for practical application of the coordinate adjustment methods. The one-dimensional schemes have been applied to both academic[1*] and nearly preactical problems.[2] They have been found to satisfy the objective of producing a more accurate solution than fixed mesh methods at the cost of more computation per mesh point. A two-dimensional extension has been applied[3] to a very simple case and has been shown to rotate and distort the mesh as necessary to refine it in regions where the solution varies sharply. The method is ready for application to the practical problems of flow over a wedge or blunt body.

Task 1. Identify Useful Coordinate Transformations

Because any generally effective, automatic method of mesh adjustment certainly depends on the individual problem and its solution, only adjustments that minimize some measure of the solution were considered. When the measure is an integral functional of the solution, the apparatus of the calculus of variations can be used to determine a transformation of coordinattes representing the mesh adjustment. In particular, the calculus of variations provides a boundary-fitting transformation, an advantage not obtained with local, nonintegral measures. An ordinary differential problem can be written as a first order system. The gradient of the dependent variables in the system is a vector with large magnitude in regions where the solution has large variation, so that minimizing the square of the gradient is an attractive and not-too-complex method for determining the mesh adjustment transformation. A second, more complex functional for minimization is the square of the truncation error vector. This functional gives a best possible mesh adjustment for the given problem and numerical solution method, but at a much larger computational cost than the gradient method. The truncation error minimization (T.E.M.) method is seen as a standard for comparison with other methods.

* Numbers denote papers in the Publication List, Section V.

The gradient and T.E.M. methods have been shown to extend in a natural way to more than one dimension for differential systems in conservation form.[3] Other functionals proposed for minimization measure mesh area, or shear distortion, or departure in a flow-problem from Lagrangian particle attachment. These functionals appear to be more specific to an application than the two basic methods. For example, a solution using an undistorted mesh would be preferred where the cost of interpolation is high. The ongoing research has been restricted to the gradient and T.E.M. methods.

Task 2. <u>Investigate Type-Dependence</u>

The implicit numerical method of the Keller box scheme is independent of type. A steady transonic flow field, for example, is treated all at once. The difference between hyperbolic and elliptic regions appears only in the number and location of required boundary values. it therefore appears that the present methods are type-independent. Tests on transonic flows in particular are to be made early in the continuing research.

Task 3. <u>Apply Transformation Method</u>

Application to a one-dimensional reactive flow-problem previously solved by several other numerical methods has shown the present methods to be of superior accuracy.[2] Application to the two-dimensional wedge and pointed slab problems is in process.[4]

III PERSONNEL

Drs. C.M. Ablow and S. Schechter have been co-investigators. Mr. W.E. Zwisler has completed his contributions, a reliable algorithm for setting up and solving the equations of a step of Newtonian interation from the given functions of the problem together with the overall organization of the computation.

IV INTERACTIONS

The third paper on "Generation of Boundary and Boundary-Layer Fitting Grids"[3] was presented at the NASA Workshop on Numeric Grid Generation

Techniques, October 6-7, 1980.

A colloquium talk on the same subject was presented at the Air Force Institute of Technology, WPAB, October 9, 1980. Particular interest in the work was expressed by Frank Bynum, FIMG/AFWAL, Lt. D.L. Martin AFIT/ENA and J.S. Shang, FIMM/AFWAL.

In telephone conversation later, November 1980, J.S. Shang suggested the gas dynamic flow over a blunt body as a problem of great interest.

V PUBLICATIONS LIST

1. Ablow, C.M., and S. Schechter, "Campylotropic Coordinates," J. Computational Physics (June 1978).
2. Ablow, C.M., S. Schechter, and W.E. Zwisler, "Node Selection for Two-Point Boundary Value Problems," submitted to J. Computational Physics.
3. Ablow, C.M. and S. Schechter, "Generation of Boundary and Boundary-Layer Fitting Grids," Proceedings, Workshop on Numerical Grid Generation Techniques, Hampton, Virginia, NASA Conference Publication 2166 (October 1980).
4. Ablow, C.M., "Mesh Adjustment for Flows Over Wedges and Slabs," manuscript partially completed for submission to J. Computational Physics.